Summary of ESP Project Gate 3 Reviewer Comments

The major thoughts and ideas of the review panel in each of the gate 3 category areas are summarized below. We have attempted to capture the main conclusions, although in some cases there may have been a dissenting opinion by one or more of the reviewers (as noted in the text). Take home messages for the ESP Project are bolded at the beginning of each section.

The members of the Gate 3 external review panel were Steve Nichols, Rod Fisher, Mel Kvaerner, and Dale Monceaux.

Strategic Fit

Biomass conversion technology is important, but the ESP Project should focus development effort on core technologies of pretreatment, enzyme production and use, and process engineering.

The ESP Project should not develop technologies specific to any feedstocks, products, or byproducts.

The general consensus of the review panel was that there was great value in pursuing development of core technologies in support of a sugar-based chemical and fuels industry. In particular, work on pretreatment/conditioning, enzyme improvements, enzyme applications, lignin handling, and process economics was considered extremely valuable. A process producing cheap sugars was viewed as highly valuable to industry and this work should proceed, but industry should eventually determine the products produced from these sugars. The project is also considered important because of the potential for production of low-cost fermentables that can compete economically and environmentally with oil/gas. Other issues such as feedstock handling, distillation, residue disposal, etc, are not as important now and won't be until an operable pretreatment/enzyme strategy is developed. Ethanol was not viewed as the best product and additionally we should not limit our feedstock choice to just corn stover.

The reviewers viewed the market potential of the general technology as attractive. They believe that much of the new technology can be leveraged to markets with higher profit margins but they want private industry to develop the specific technologies. Likewise, the reviewers believe that byproducts can be profitable in the correct markets and they do not want NREL to develop those products, technologies, or markets. Instead NREL should characterize the materials and leave development for industry specialists who understand the products and markets.

One reviewer noted that the strategic fit was not proven.

Market/Customer

According to the timeframe presented, bioethanol production will not be possible until 2005 (after the market's growth will have peaked) so bioethanol will need to compete with starch-based ethanol facilities that are part of a mature industry and will have already paid off their capital expenses.

The Market and Customer

The reviewers had several concerns with the project's market focus and stated that the market criteria were not presented adequately. Their first concern was the economic feasibility of bioethanol. They recognized that although the process is not feasible in the time frame proposed it could be in some special situations (e.g., zero or negative cost feedstocks, large incentives, regulatory requirements with the phase-out of MTBE). On the other hand, they stated that they did not understand the market economics any better than we did and were not sure that anyone had a good grasp of those economics. Historically, the fuel ethanol market has been uncharacterized due to the number of market drivers. Those drivers include the government (policy, legislation, and tax programs), the oil industry (fuel distribution and competition for ethanol), and international politics (OPEC policies). One reviewer recommended getting insights from the ethanol and oil industries to improve market characterization.

The ethanol industry is predicted to grow dramatically in the next 4 years and then become more stable. However, the enzyme-based technology now under development will not be ready for at least 4 years, and any new bioethanol facility will need to compete with starch facilities that have already paid for their capital investment. That is not a good business situation. Widening the focus to sugar and stabilization of the sugar market is meritorious.

Business Risk and Showstoppers

The reviewers stated that several business risk issues exist but are outside the scope of the ESP project. Those include enzyme costs and availability, capital investment issues, potential profitability of early facilities, and technology ownership and warranties.

The reviewers stated that the current reductions in enzyme cost are notable but they are concerned about the difficulty of further reductions to reach cost targets. Those concerns are based on enzyme development history, especially with amylases. The current price reductions in amylases have taken over 30 years to achieve and enzyme manufacturers still do not produce alpha- and gluco-amylases costing 1¢ per gallon of produced ethanol. Expecting similar cost reductions with cellulase, as well as developing the necessary cellulase production volume capacities, in 3 years is overly optimistic. Still, the project's schedule is based on that expectation.

The reviewers also stated that a $200,000,000 facility with be difficult to finance and build without government intervention and still the first generation plants will not be able to cash flow on purchased feedstocks. One reviewer was concerned about technology

ownership, licensing fees, and process guarantees not being included in the economic analysis. Those costs could be substantial and further reduce the probability of success.

Technical Feasibility and Risks *(primarily addressing technical development controlled by the ESP Project)*

The primary technical risk in this project is delivery of low-cost cellulase enzymes by 2004 so the project can achieve its 2005 goals.

Although, some risks were noted on the business and economic aspects of this project with its focus on production of ethanol from corn stover, the review panel believed that the project was technically feasible with no obvious showstoppers (beyond economics), but felt that the project relies too heavily on the successful development of low-cost cellulase enzymes. The reviewers repeatedly emphasized the criticality of developing and making available low-cost enzymes. Other possible showstoppers besides low-cost enzymes mentioned by the reviewers included stover/soil/water health and stover supply chains. Concerns were raised on the availability of low-cost corn stover, its storage and handling, engaging the farmer, politics, and doubts were expressed that stover could be obtained for less than $20/ton. Other minor concerns were on metallurgy of the pretreatment equipment, hydrolysate conditioning (overliming, ion exchange, and the fate of phenolics), and the value of the fermentation residue (burn or use as animal feed).

As the project moves forward, the reviewers thought it would be necessary to revisit our technical and economic assumptions and generate the missing information as appropriate. Also noted was the need for a flexible and robust process and/or a breakthrough on cost or government funding to develop the industry.

Competitive Advantage *(focus on economics)*

The economic analysis needs to be made more rigorous.

The reviewers had several concerns with the economic analysis that was presented. Those include a statement that the $200,000,000 capital investment is too optimistic because of nth plant assumptions, a 96% on-stream time, and other reasons. A dissenting reviewer thought that $200,000,000 was reasonable for a 1st generation plant. One reviewer stated that used equipment would not be possible in the first plants and therefore should not be considered as an option. Another reviewer stated that the understanding of long-term capital and funding drivers was inadequate. The operating costs were also considered too optimistic because they are for an nth plant, exclude technology licensing (e.g., fermentation strain) costs, and assume that power can be sold at 4¢/kW-hr. The reviewers stated that the probability of ethanol prices rising to $1.50/gal is much greater than the probability of technology improvements reducing the price to $1.10/gal. Cost breakthroughs, not incremental improvements, are needed to achieve the $1.10/gal goal.

The reviewers requested further improvements to the economic analysis, including the following: Monte Carlo/sensitivity analysis to prioritize critical factors and present risk and evaluation of feedstock cost at the hydrolyzer (instead of the plant gate) to compare stover to other feedstocks.

Legal/Regulatory Compliance *and (Public Perception Issues)*

Continue life cycle analysis and increase its rigor.

Although there were no specific concerns in this area, it was noted that this new industry must pay attention to legal/regulatory compliance and the need for safety, environmental and operability reviews. Additionally, there may be some constraints during the permitting process, particularly in dealing with the various state requirements.

The life cycle analysis was highly viewed and we were encouraged to continue this work and to use it as a tool to engender public support. The caveat is that the methodology must be scientifically very sound and rigorous. We were also encouraged to make a stronger case for the benefits to the rural economy and to develop a plan for getting this message out.

Plans *(Stage 3 plans, timelines, staffing, and budget)*

The projected resources are insufficient and the timeline too short for the project's goals.

The reviewers stated that the plans for future work are very good. They like the use of a pilot plant followed by a demo plant to determine the issues with continuous, integrated operation with recycle. However, one reviewer believed that this stage gate 3 review was premature and that the project should still be in stage 2. He allowed the project to conditionally proceed into the first year of stage 3.

The reviewers felt that the timeline and resource assessment for stage 3 were overly optimistic. They believe that the plans need more time (especially if any problems are found on the first test) and that more personnel are needed to achieve the goals. They were especially concerned with the limited resources in this project compared to the enzyme and pretreatment project areas because this project plays a central role and if it fails all other projects are likely to fail as well.

The demonstration plant requirements were also a concern of the reviewers. They believe that partnering by March 2003 is too early and that the partnership requirements for a demonstration-scale facility are too large for a company to take that risk.

The reviewers are concerned about how government and industry will work together to commercialize this technology. They expressed concerns that the government would have

too many contact points for an industrial partner. One suggested solution to that problem was to utilize the model of the enzyme contracts. Other components of the project, or even the whole project, could be contracted out to private industry.

Commercial Opportunities *(Potential Partners)*

The project should attempt to partner with an existing industry (e.g., dry milling) and build the first plant as an add-on.

The team supported the concept of partnering with an existing industry (in particular dry millers) as way to start this industry. The concept of adding on to an existing facility was noted for its potential to reduce cost and risk, perhaps improving the chances for the first lignocellulosic biomass-utilizing plant to be built and operated. It was also noted that there could be similar opportunities in several other industries, particularly if corn stover was not the feedstock. Examples of other feedstocks of potential interest include pulp mill residues, bagasse, and rice mill fiber.